

Exploring Oceanic Source Regions And Moisture Transport for Extreme Floods: Ohio River Basin

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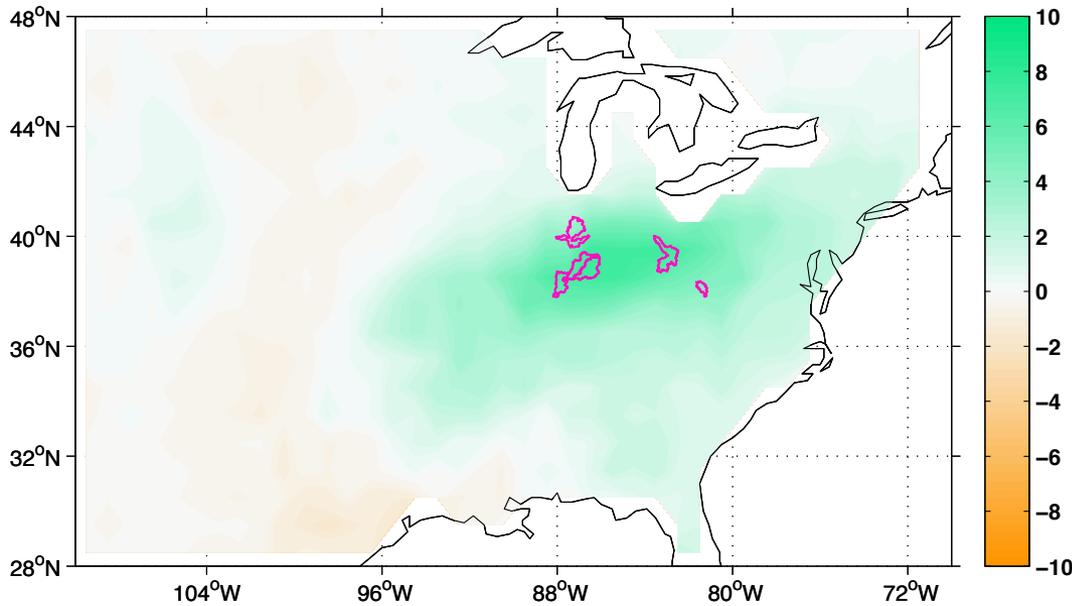
Global Flood Initiative

Key Points

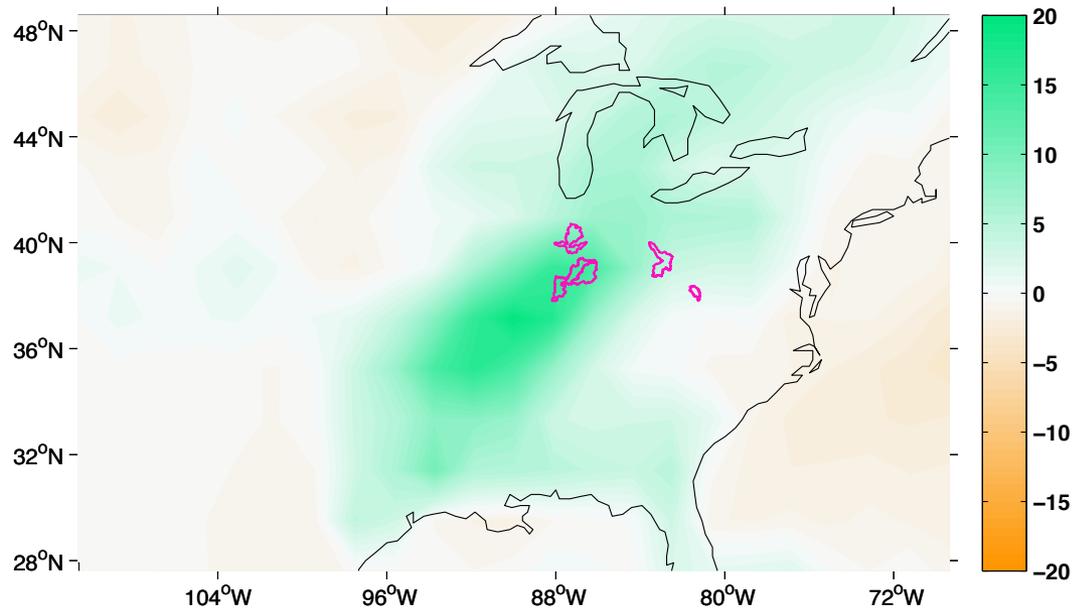
- **Extreme Floods in Mid-Latitudes**
 - ▣ Antecedent Soil Moisture (past rain) AND persistent, rain event with basin scale coverage
 - ▣ Tropical Moisture Exports associated with strong and persistent circulation anomalies ?=? Atmospheric Rivers
 - ▣ Synoptic weather modulated by larger scale dynamics?
- **Diagnosis of 20 >10 year flood events in the Ohio River Basin + Euro events with tropical Atlantic Moisture sources**
 - ▣ Examine associated circulation parameters
 - Event attributes (Apr2011 Ohio R, Jan 1995 France-Germany, 8 events UK)
 - Composites over 20 events for Ohio River Basin (MAM)
 - 20th Century Reanalysis V2 data, MERRA, Knippertz Wernli TME, USGS
 - Evidence of consistent patterns and organization across events suggesting potential predictability – FLOODS are DETERMINED and not just RANDOM
 - Circulation clusters/hidden states relate to MJO/ENSO – potential medium to long range predictability?

Precipitation Anomaly

a) MAM 20 Event Composite Days -9 to 0



b) 18-27 Apr 2011

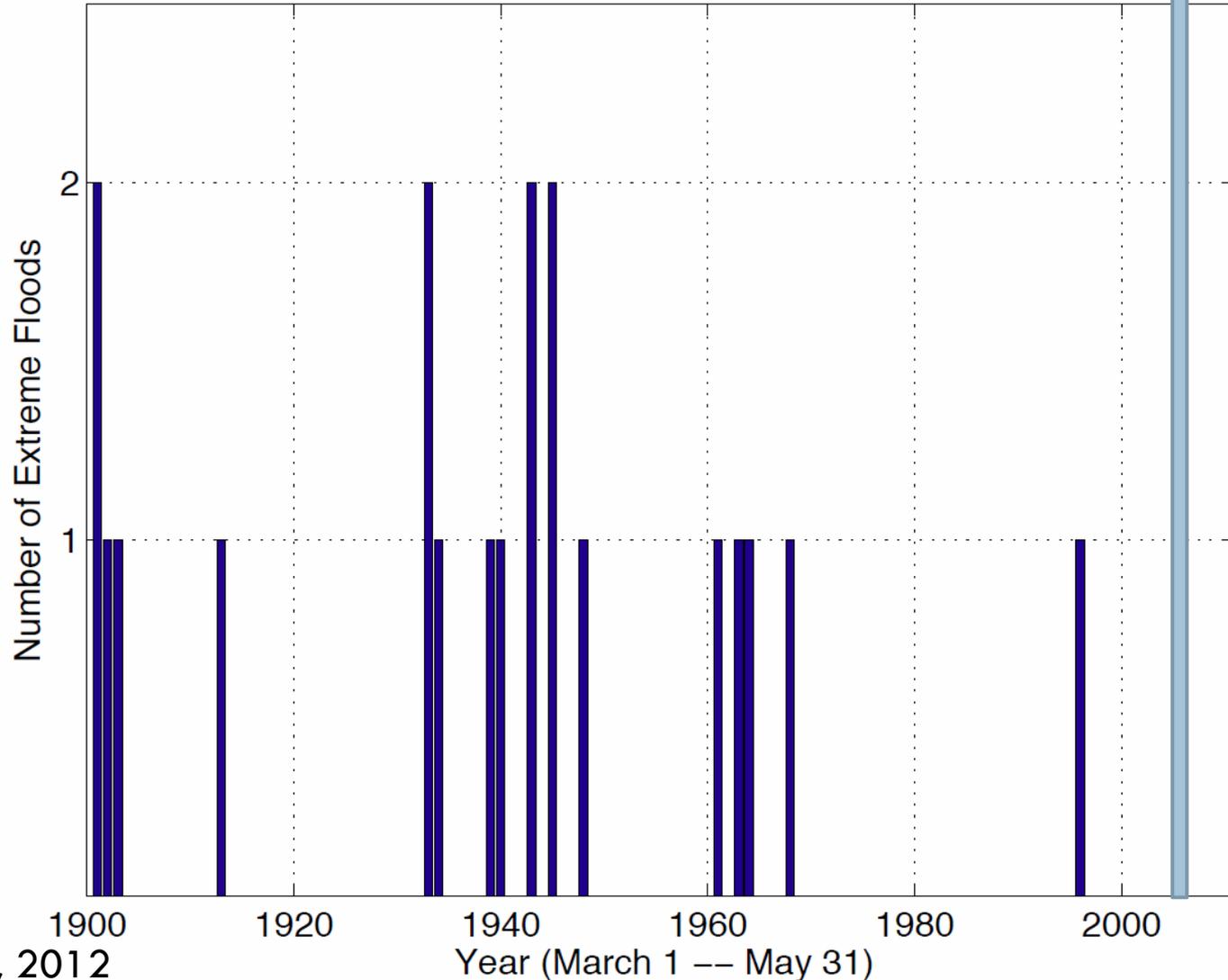


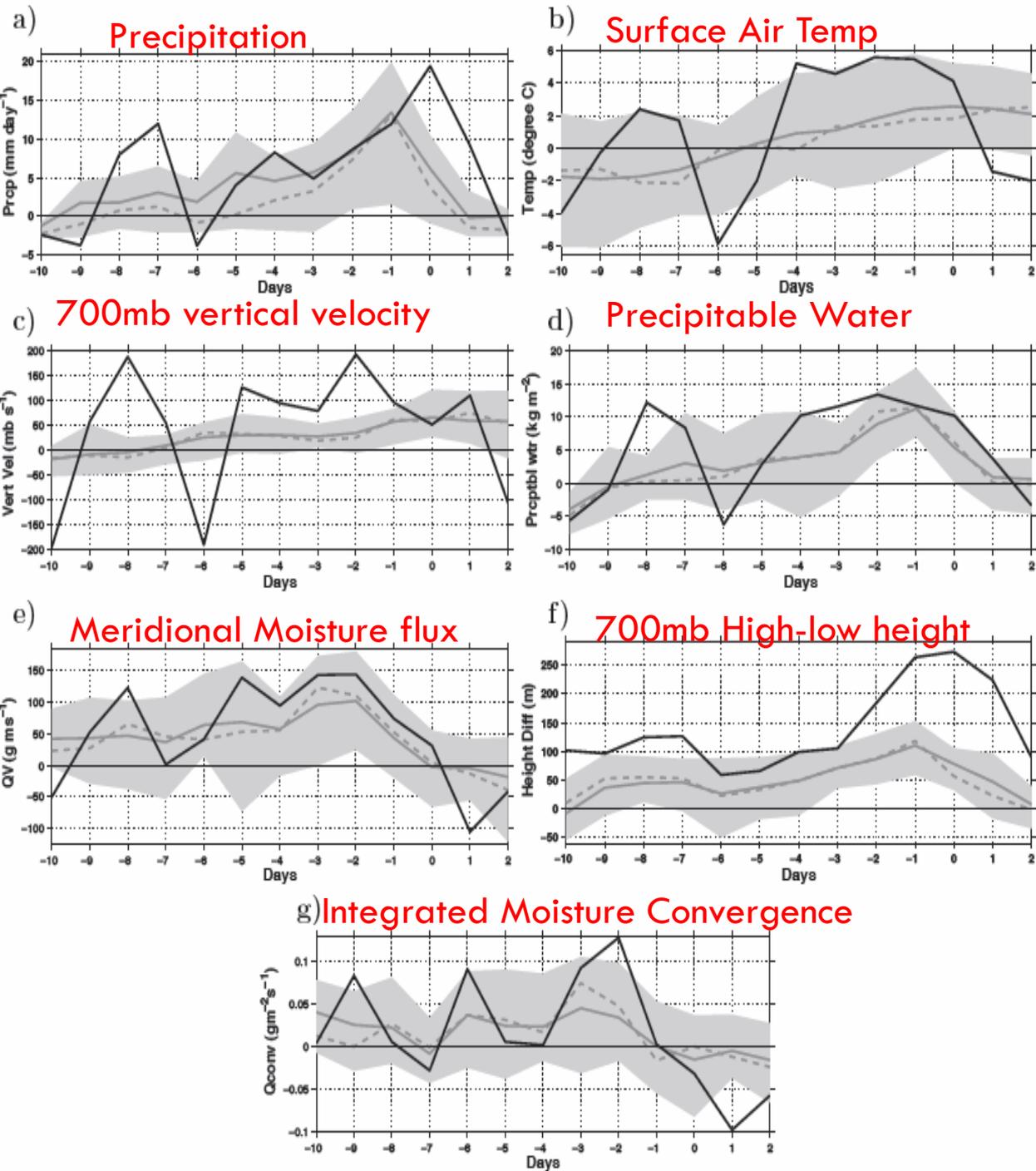
Precipitation anomaly in mm day⁻¹ of a) average of 20 historical, 20th century floods in large river basins in the Ohio Valley (basin outlines in hot pink) and b) average of 18-27 April 2011.

Large Scale events

Floods exceeding the 10 year flood across Ohio River sub-basins

Ohio Extreme Flood Series 1901–2010





Anomaly time series of variables averaged over the Ohio River basin (a-d), between 100°W and 90°W and 28°N to 42°N (e -g), from days -10 to day 2 (flood is day 0).

20-event composite mean (solid grey)

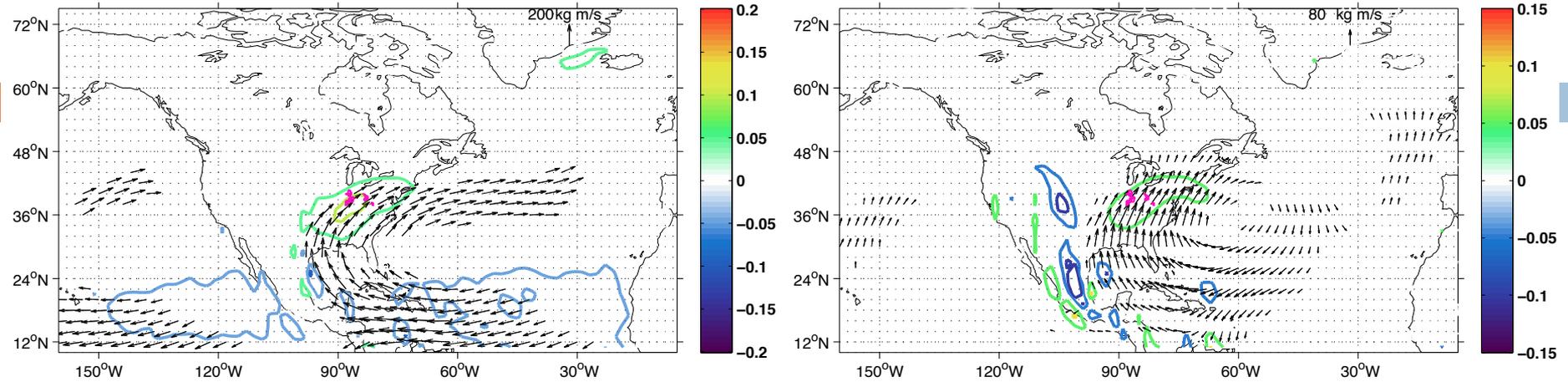
median (dashed grey)

25th to 75th percentile spread (shaded grey)

April 2011 event (black).

Surface-600 mb Moisture Flux and Convergence

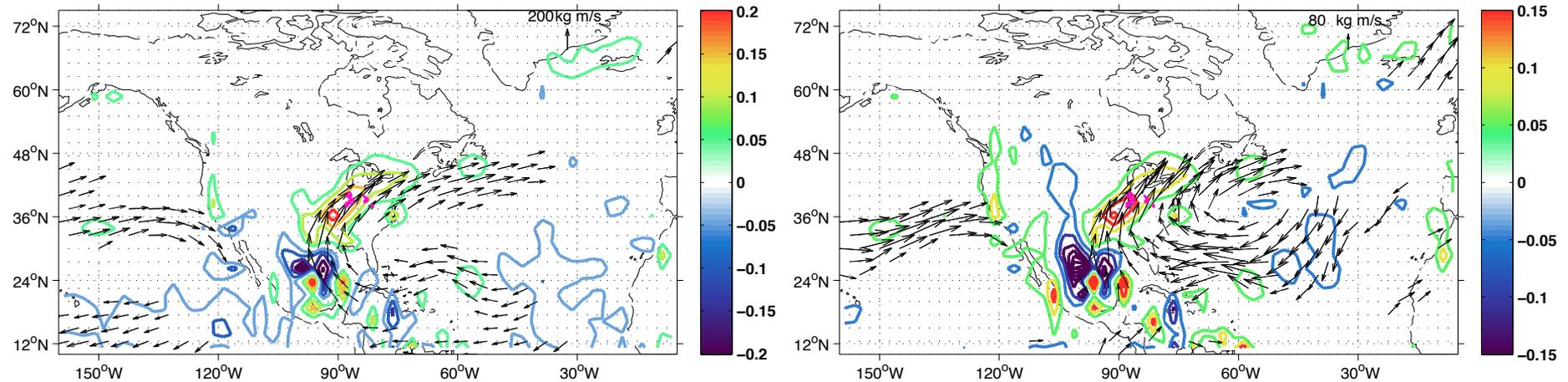
a) MAM 20 Event Composite Days -9 to 0



Full field

b) 18-27 Apr 2011

Anomaly



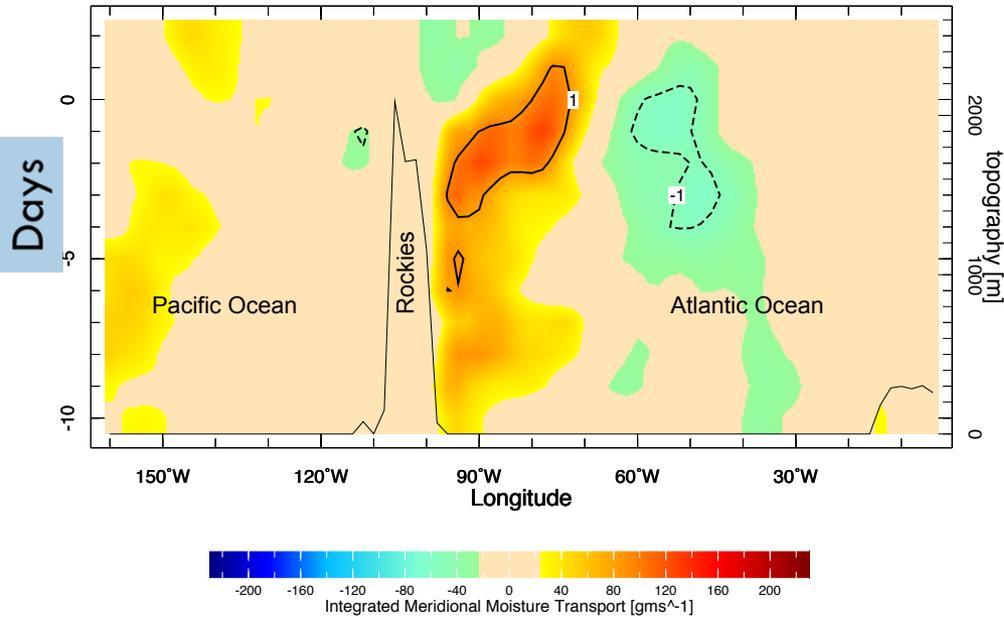
(a) Vertically integrated 600 mb - surface moisture flux in kg m s^{-1} (strongest 20 percent of values shown as arrows) and moisture convergence in $\text{gm}^{-2}\text{s}^{-1}$ (contours) for drainage basins (size $> 10^3 \text{ km}^2$) within the Ohio Valley averaged over the nine days leading to the 10-year flood.

Nakamura et al, 2012

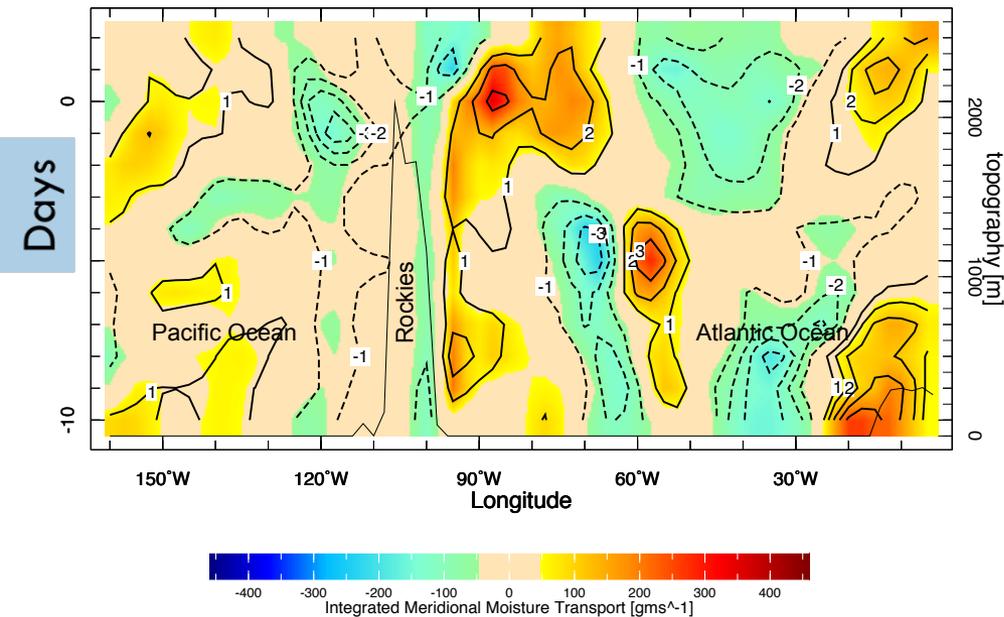
Large-scale anti-cyclonic moisture flow & convergence (Bermuda High)

Surface-600 mb Integrated Meridional Wind ($\text{kgm}^{-1}\text{s}^{-1}$) (contours) and Moisture Transport (gms^{-1}) (colors) at 25 N, Days -10 to 2

a) MAM 20 Event Composite



b) 27 Apr 2011



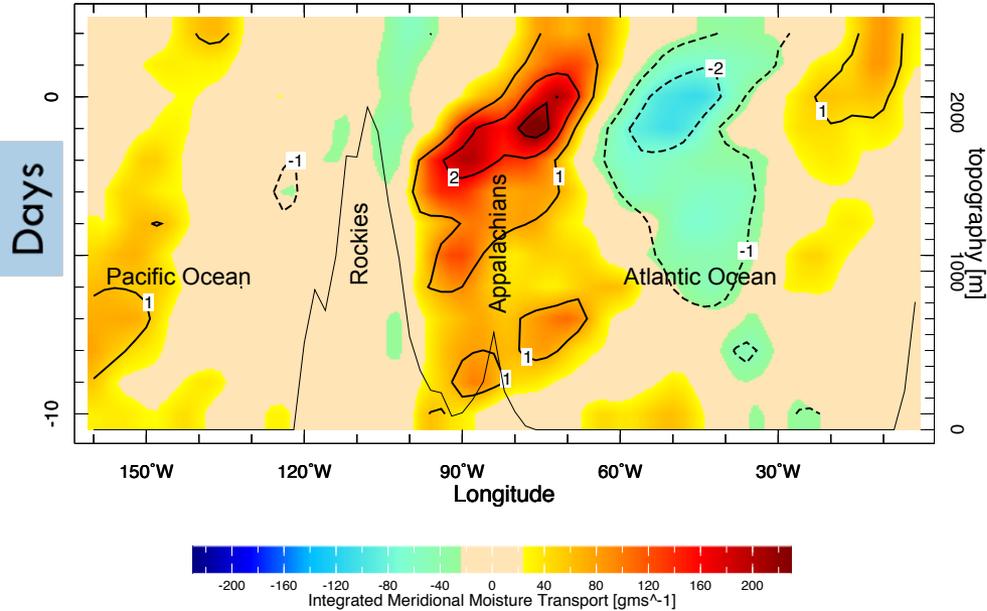
Moisture channeling
between the Rocky and
Appalachian mountains
Hovmoller plot
(600 mb-surface)
meridional wind
(contour) and moisture
transport (colors)

25N

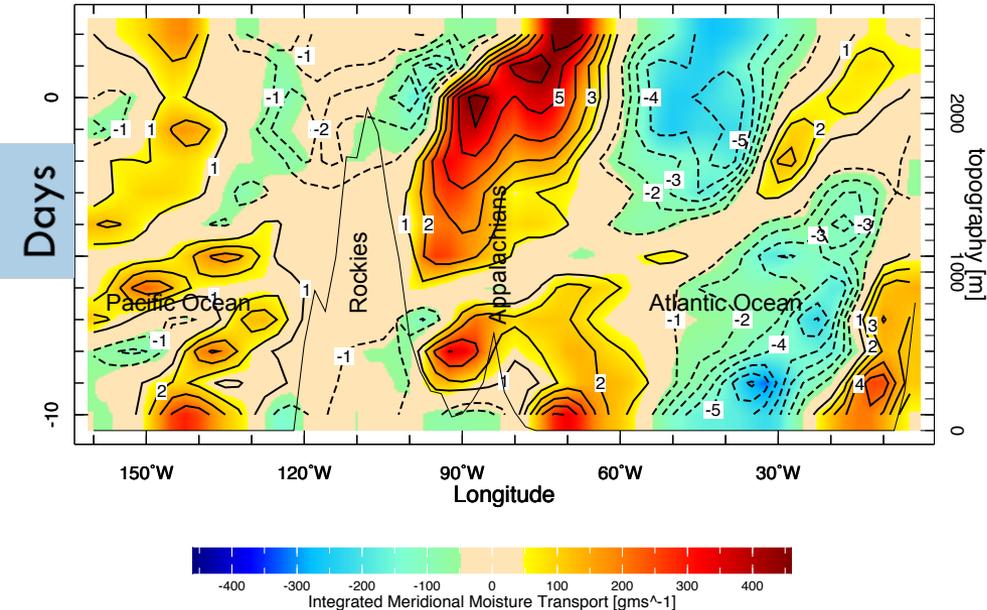
Nakamura et al, 2012

Surface-600 mb Integrated Meridional Wind ($\text{kgm}^{-1}\text{s}^{-1}$) (contours) and Moisture Transport (gms^{-1}) (colors) at 35 N, Days -10 to 2

a) MAM 20 Event Composite



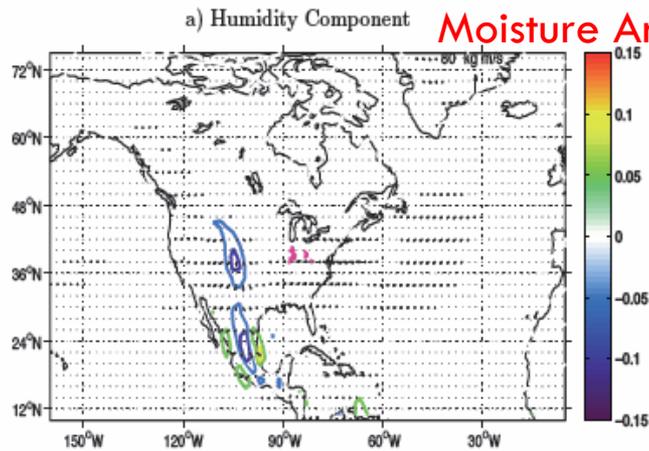
b) 27 Apr 2011



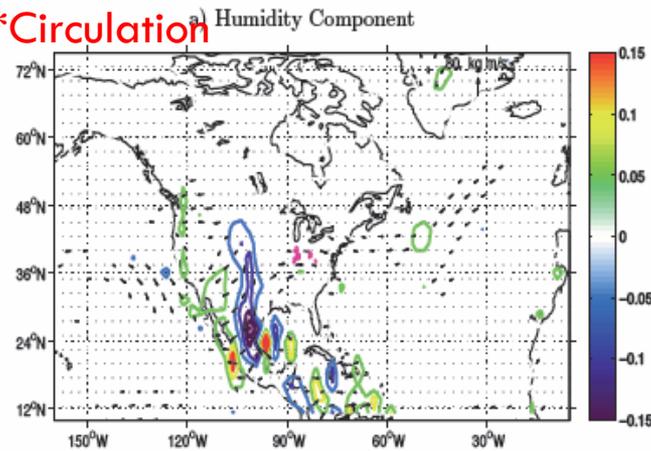
Moisture channeling
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35N

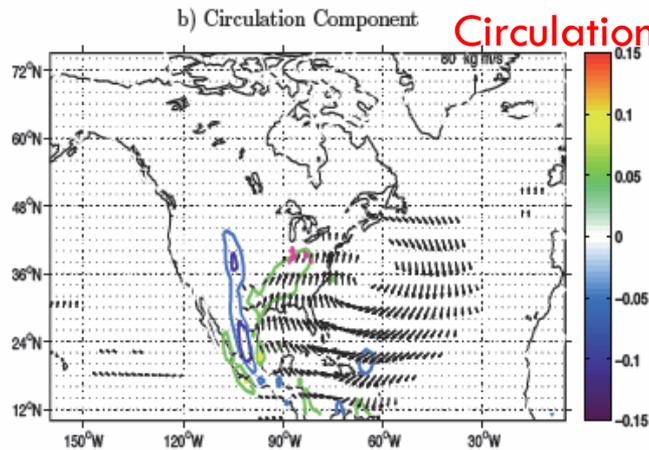
Nakamura et al, 2012



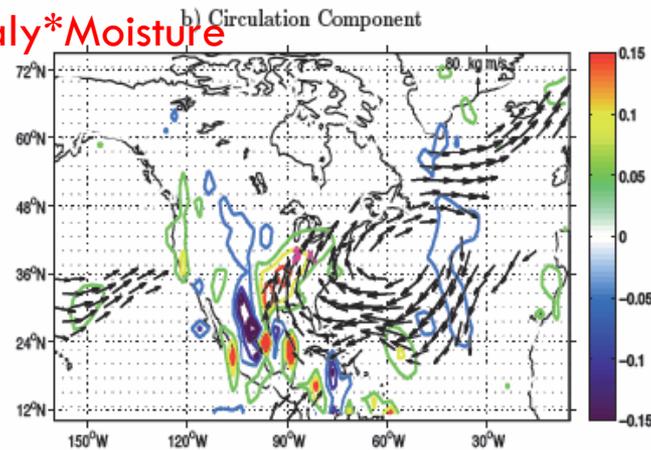
Moisture Anomaly * Circulation



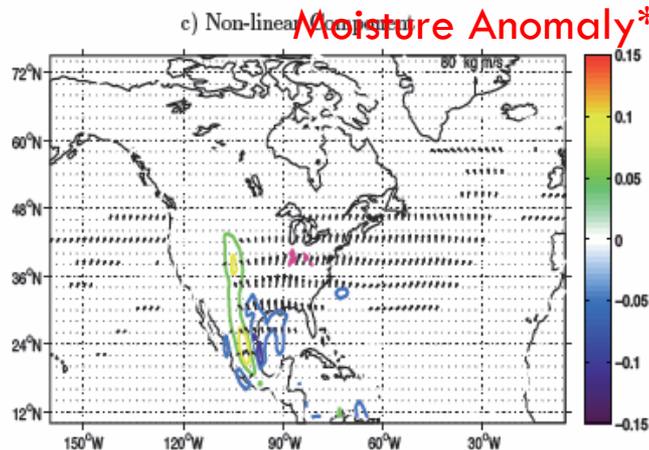
Anomaly field is dominated by the advection of the moisture by the anomalous circulation



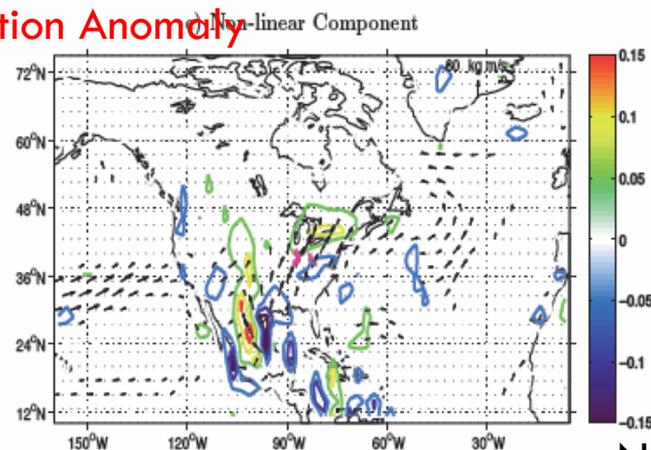
Circulation Anomaly * Moisture

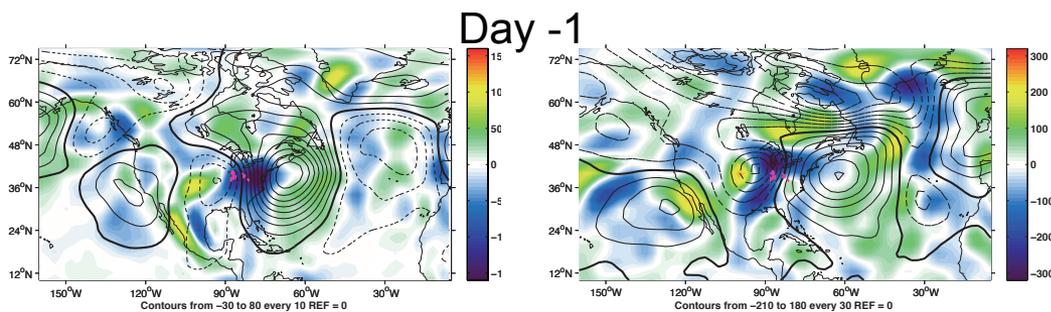
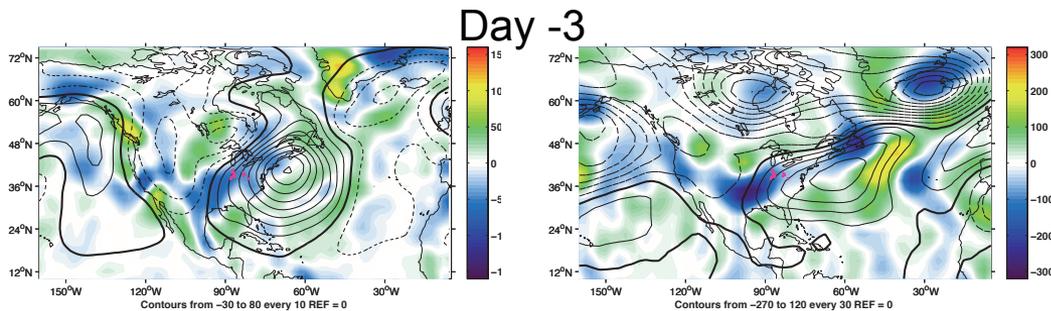
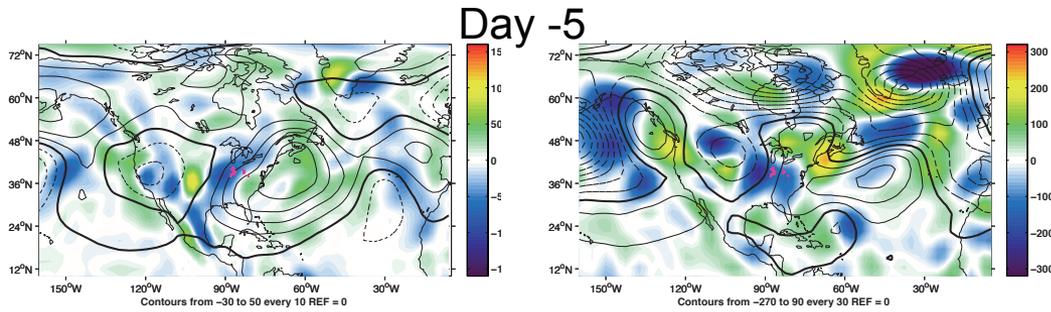
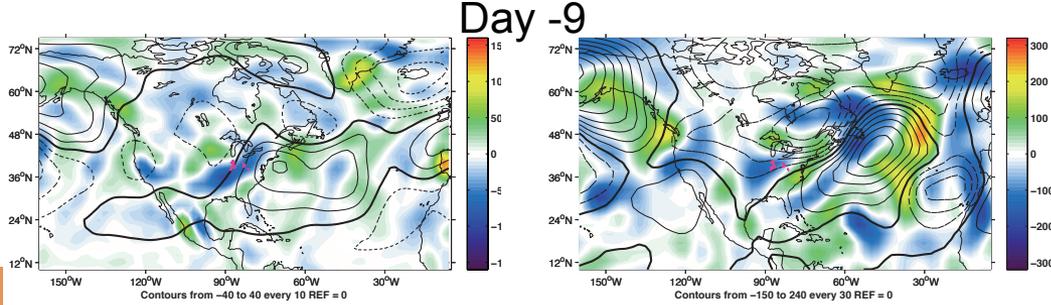


20 event Composite (left)
2011 event (right)



Moisture Anomaly * Circulation Anomaly





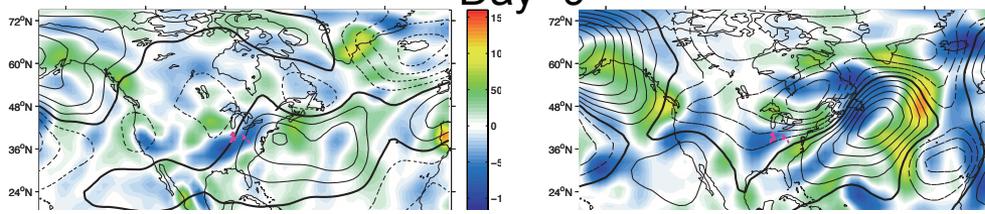
700 mb geopotential height anomalies (in m) in contours and vertical pressure velocity (in mb day⁻¹) colors (blue/purple is upward motion).

Left: 20 event average

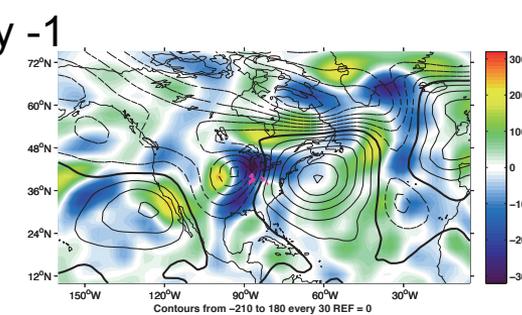
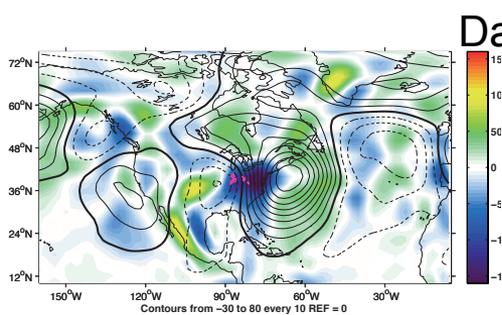
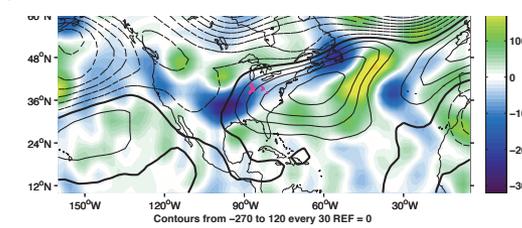
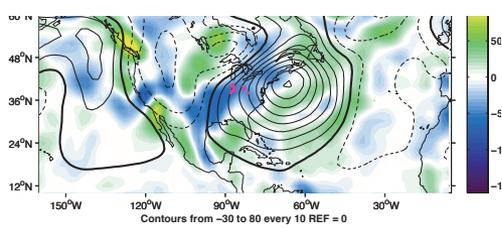
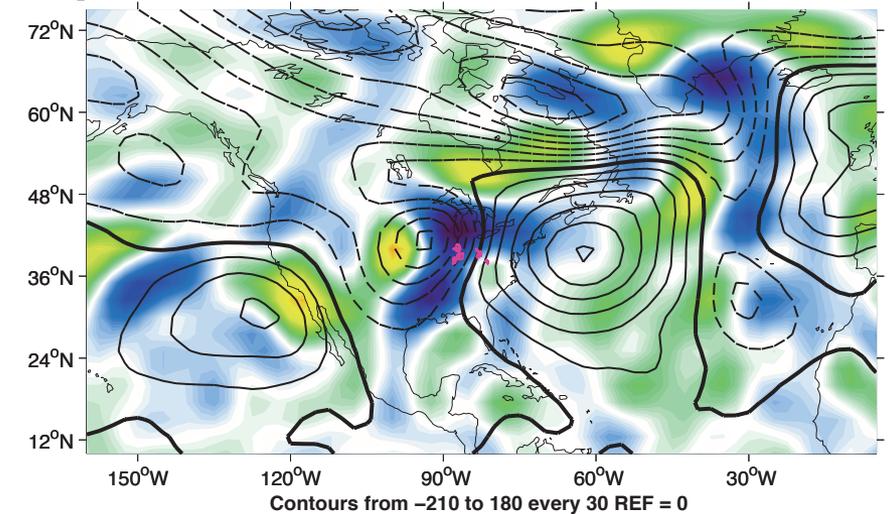
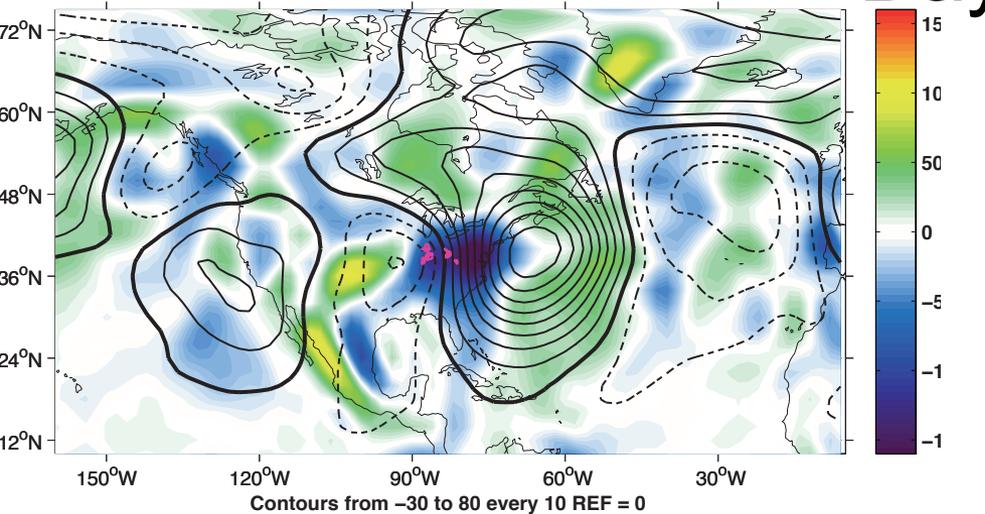
Right: April 2011

The dipole pattern of a significant positive geopotential high anomaly to the east of the flooded basins together with a weaker but negative anomaly to the west, are established on day -9 and persist throughout the days leading to the flood event.

Day -9

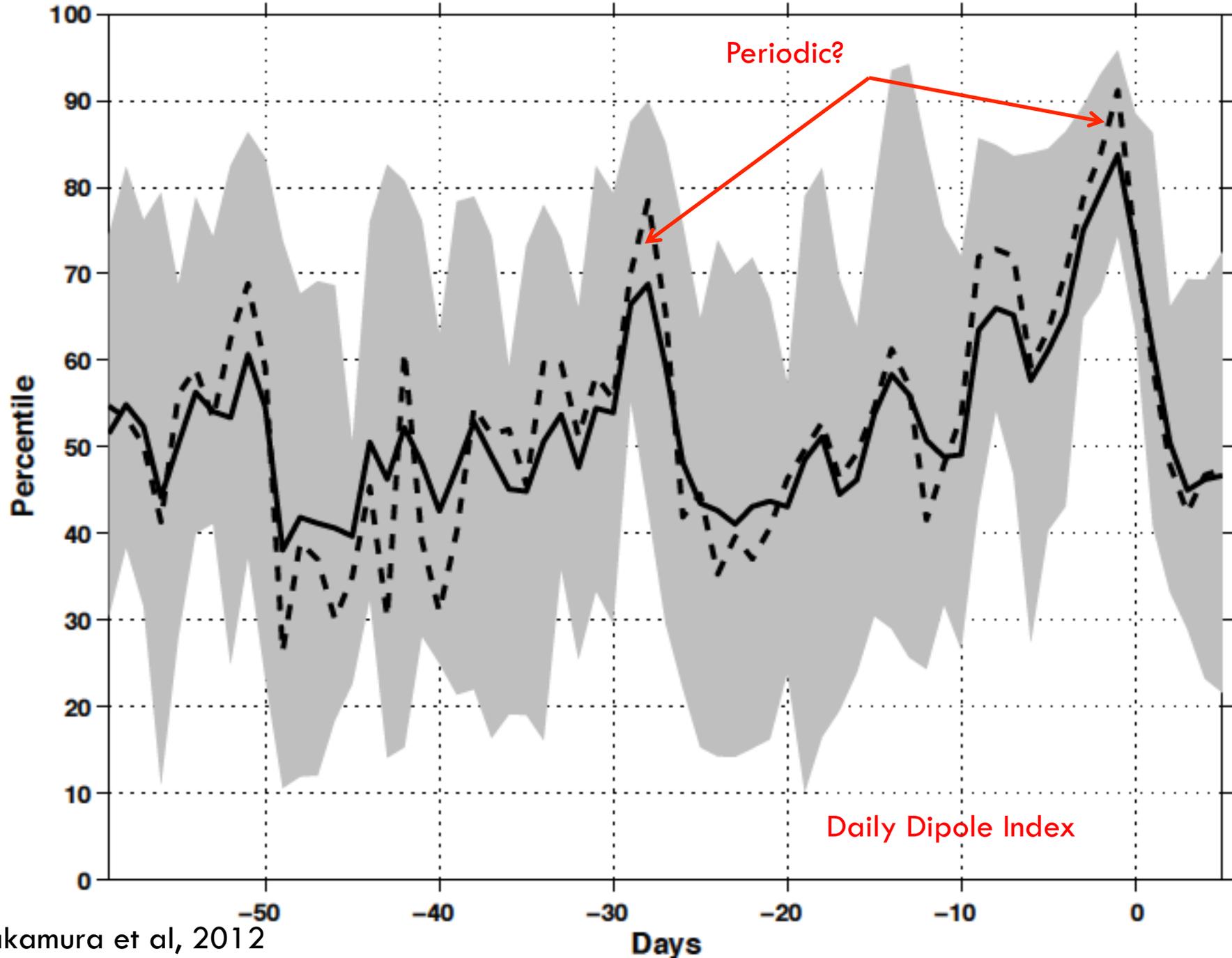


Day -1

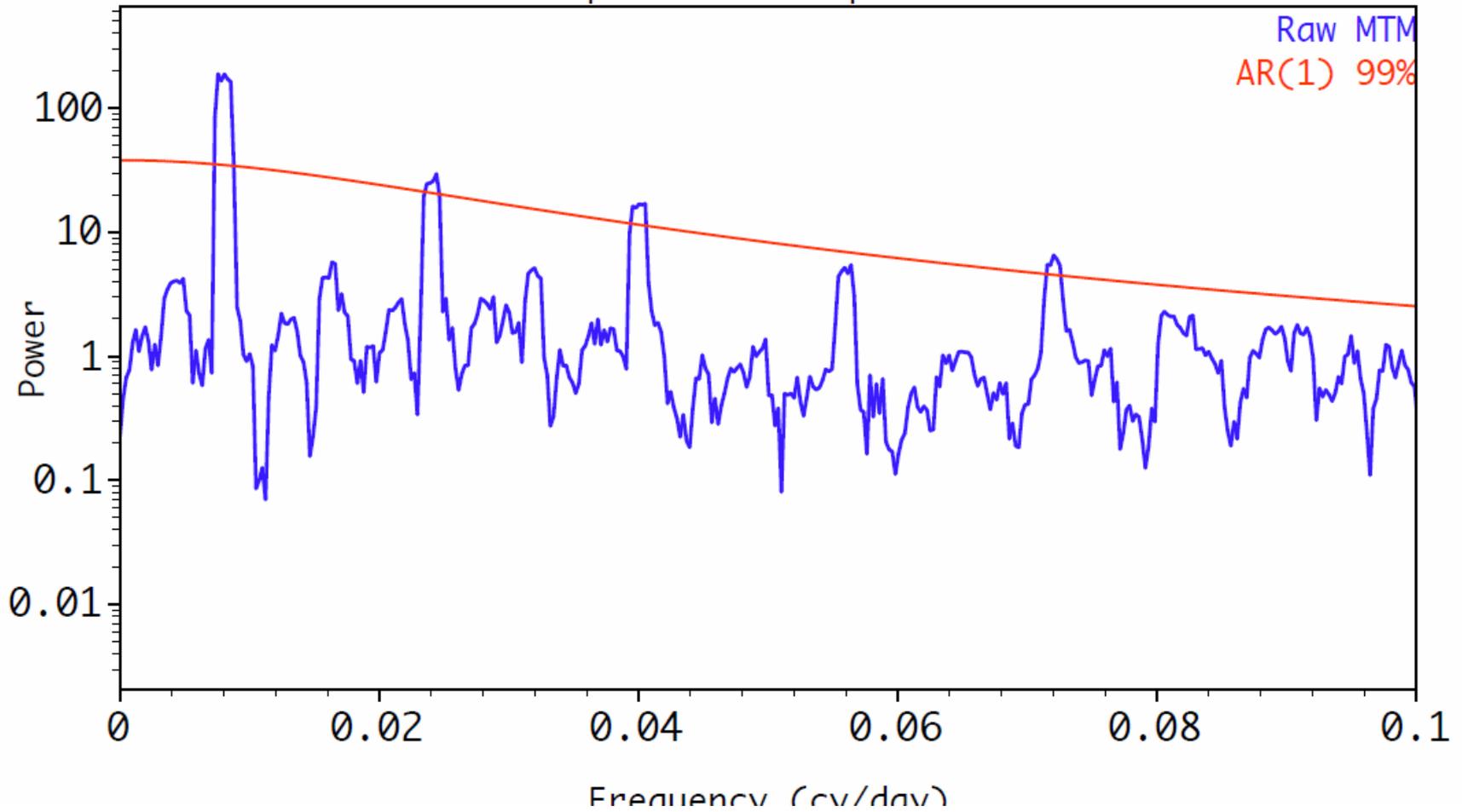


The dipole pattern of a significant positive geopotential high anomaly to the east of the flooded basins together with a weaker but negative anomaly to the west, are established on day -9 and persist throughout the days leading to the flood event.

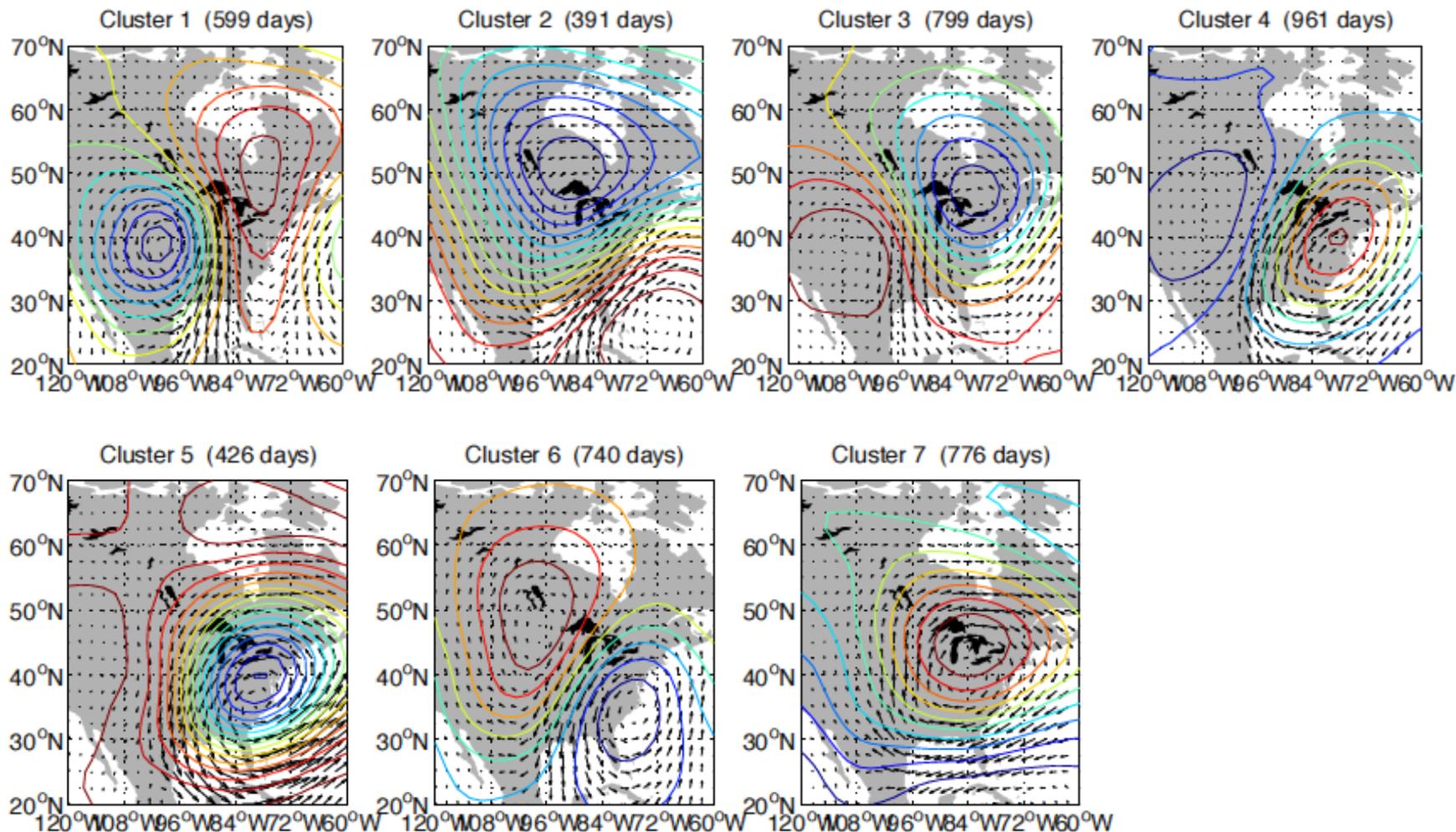
Days vs. Percentile, Mean (Solid), Median (Dashed), 25th to 75th (Shaded)



MTM Spectrum of Dipole Index

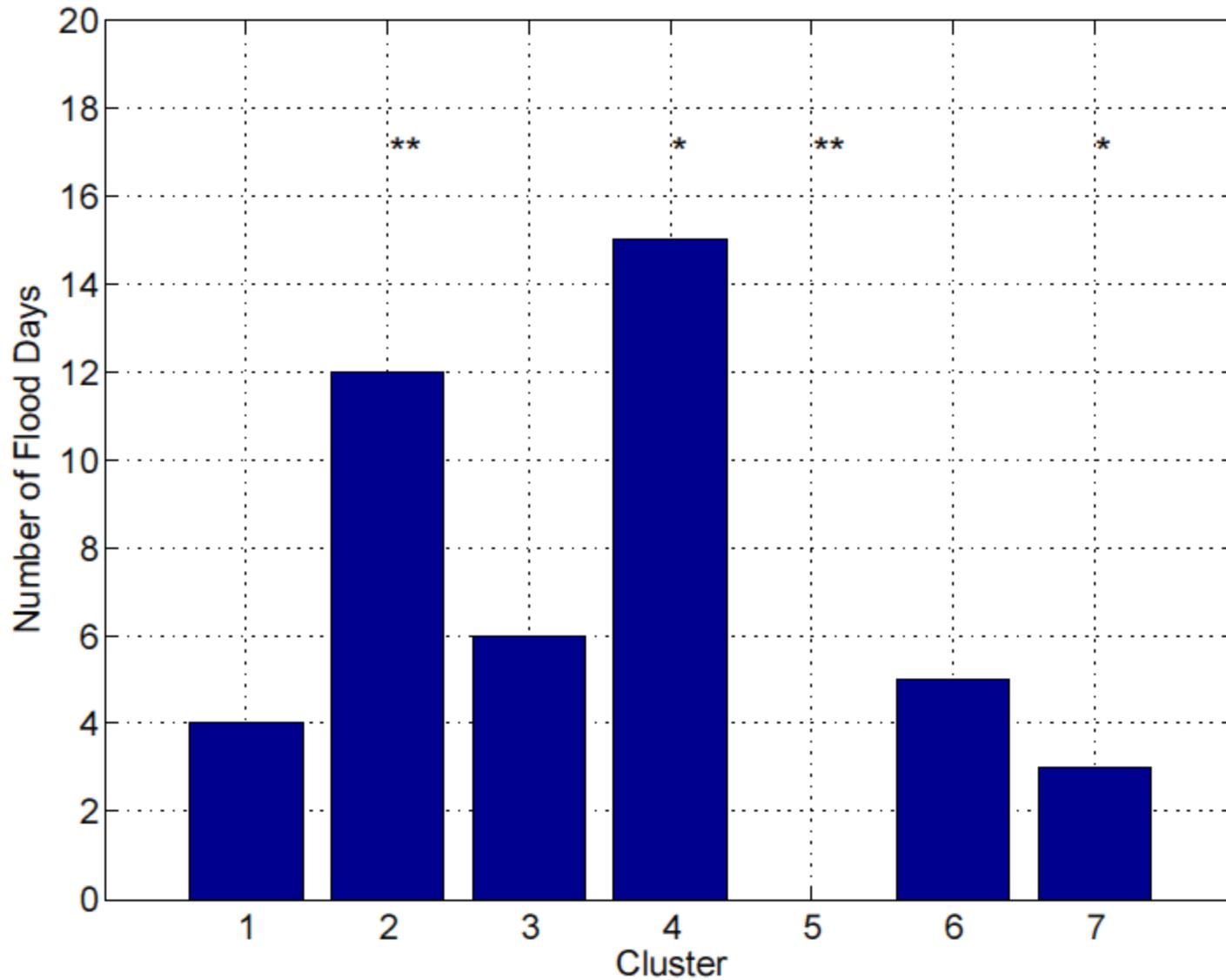


Red Noise Null Hypothesis
~13, 26, 39, 129 day cycles?



Circulation Types: 700hPa Geopotential Height and vertically integrated moisture composite anomalies for 7 K-means clusters identified using 3 leading PC's of geopotential heights for the region (30-50N, 105-75W)

Regimes on Flood Days (-9 to 0)



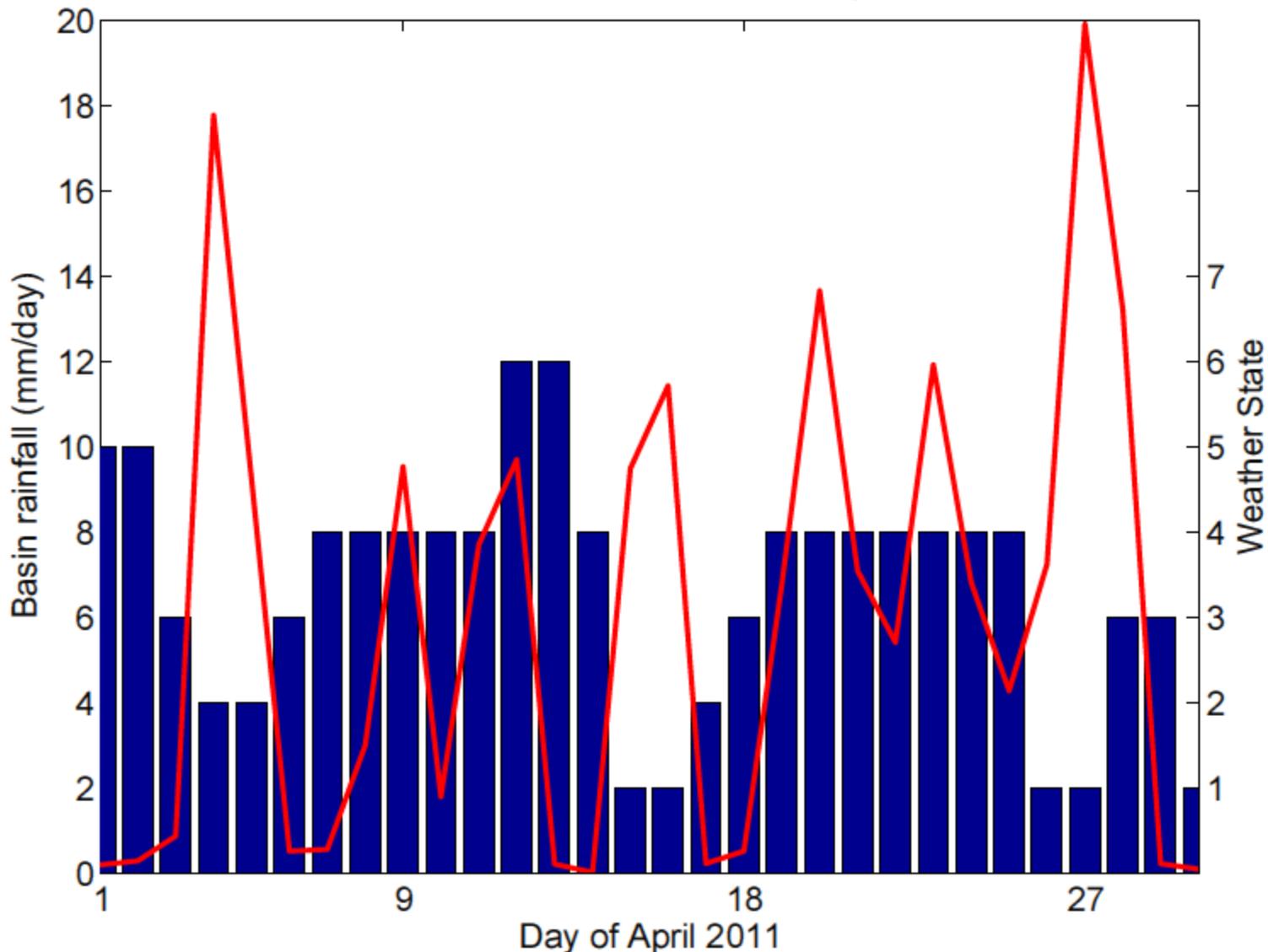
4,2,3,6,7,1 most common Flood, 5 no flood

Analysis for most recent 5 events prior to 2011

Robertson et al, 2012

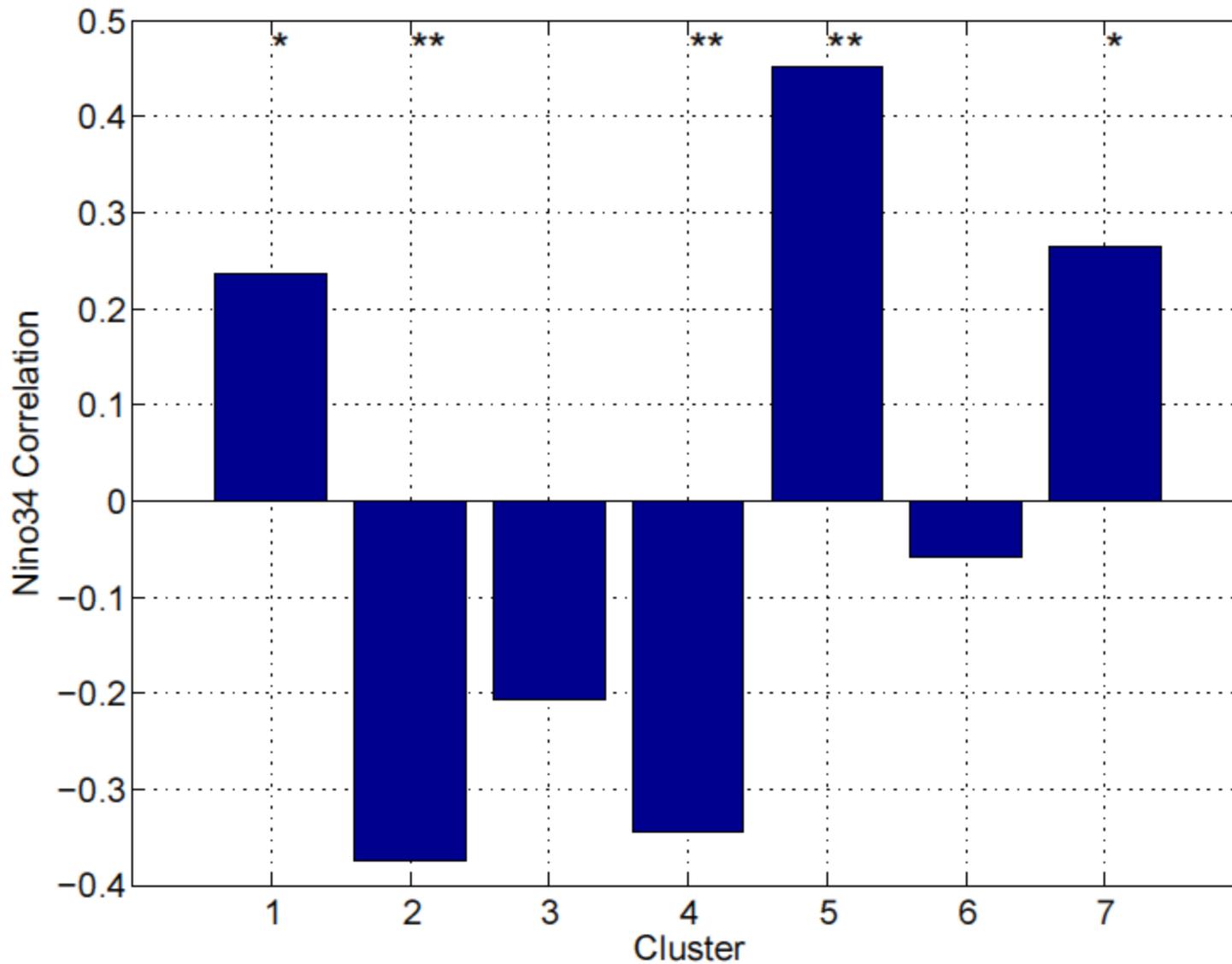
** (*) 95% (90%) significant from bootstrap

Basin rainfall vs Weather States, April 2011



Daily rainfall (red curve), and clusters (blue bars) for April 2011 event (not included in original classification)

Robertson et al, 2012

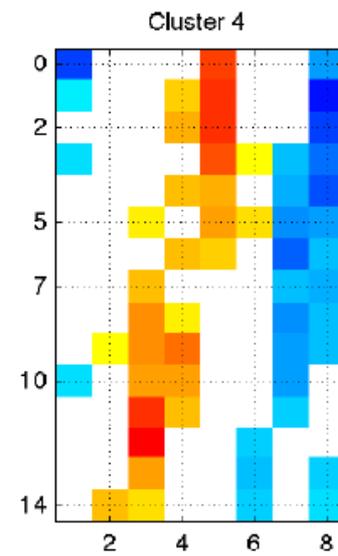
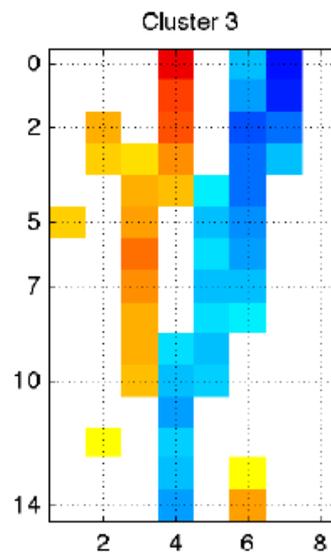
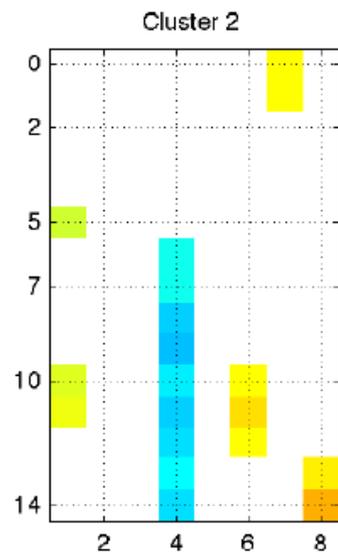
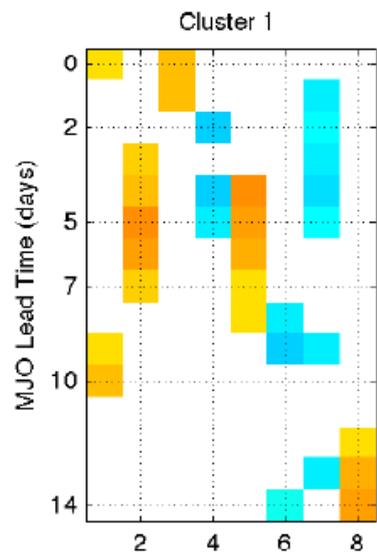


4,2,3,6,7,1 most common Flood, **5** no flood **4,2,6,3** La Nina, **5,7,1** El Nino

MAM daily data correlations

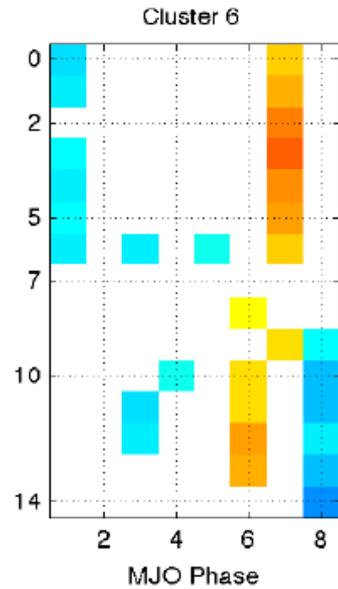
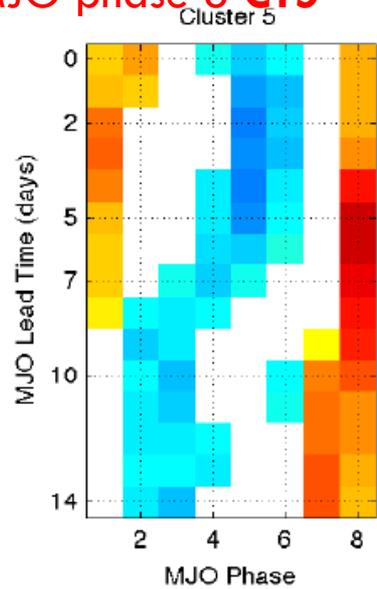
Robertson et al, 2012

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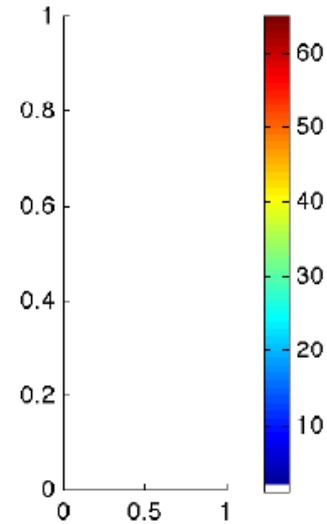
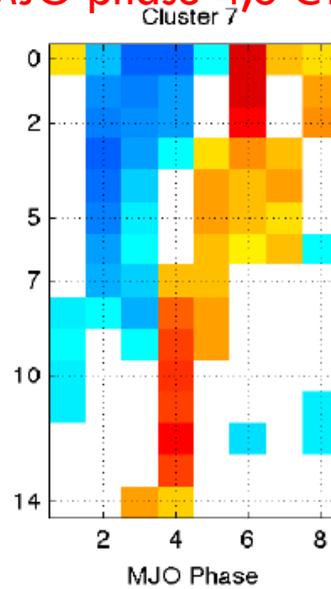


MJO phase 3,5 CT4

MJO phase 8 CT5



MJO phase 4,6 CT7



Cluster Frequency relative to MJO phase, for up to 14 day lags relative to MJO

Robertson et al, 2012

Summary

- Our exploratory analyses suggest that **persistent, consistent** anomalous **circulation** and moisture transport **patterns** may **determine** large floods in a specific region ← **implications** for C.C. scenarios and prediction.
- Tropical Atlantic moisture sources and associated circulation patterns that focus meridional transport into the **US Midwest**, along the **East coast**, and into **N. Europe** can be identified even in across event composites. ← **flood determinism**
- For such events, persistent wave like patterns and synoptic circulation types potentially related to ENSO and MJO activity may be identified ← **Tropical SST/OLR Anomalies?**
- Short to medium range probabilistic forecasts of the extreme events, as well as seasonal stochastic simulation may be feasible, and are being explored.